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SETTLEMENT CORRECTION AT LA GUARDIA FIELD

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SETTLEMENT CORRECTION AT LA GUARDIA FIELD

By John M. Kyle[1]

Synopsis

A settlement of about 5 ft in the period prior to August, 1946, permitted sea water to cover parts of the runways at La Guardia Field (New York, N. Y.), thus putting the field out of operation on several occasions. This paper describes the steps, with the field in full operation, taken to prevent a recurrence of this condition.

Introduction

The City of New York, in August, 1946, approached The Port of New York Authority with the request that it review the airfield situation in the metropolitan area with a view to taking over the maintenance and operation of the city's airports. Among the serious problems involved in the review of the entire program was the maintenance of La Guardia Airport as an operating facility during the rehabilitation of the field. To explain this, it is necessary briefly to review the conditions as they existed at that time.

The geology of the site of La Guardia Airport is typical of glacial areas common to the north shore of Long Island.[2] The crystalline bedrock occurs at from 100 ft to 200 ft below sea level, sloping generally from the northwest to the southeast. Overlying the rock are clays, sands, and gravels of the Cretaceous period, followed by stratified glacial drift and till of the Pleistocene moraine, and, finally, by the recent soft organic silt and clay still being deposited.

Prior to 1928, the site was occupied by the North Beach Amusement Park. The upland area was confined to a relatively small area of about 55 acres north of the present hangars[3] 1, 3, and 5 (see Fig. 1) and rose to an elevation about 40

Note.—Written comments are invited for publication; the last discussion should be submitted by **May 1, 1951.**

[1] Chf. Engr., The Port of New York Authority, New York, N. Y.

[2] "The Geology of Long Island, N. Y.," by Myron L. Fuller, U. S. Geological Survey, Washington, D. C., 1914.

[3] "New York Municipal Airport," by Brehon B. Somervell, *Civil Engineering*, April, 1940, p. 202, Fig. 1.

ft above sea level. In 1928–1929, the North Beach Airport was constructed. Rock bulkheads were built under the water, more or less parallel with the north shore line, and the area was extended by filling the intervening space with soil from the higher uplands to produce an airfield of about 105 acres. Construction of the present airfield was begun in late 1937, extending the area to about 560 acres by the addition of fill obtained from Rikers Island (in the East River), which was spread over the soft silty clay deposits on the north and east sides of the old airport, bordering Flushing Bay. During this period, the surface elevations in the area of the old airport were left at their original grade of about El. +14, whereas in the newly extended areas, runways and taxiways were generally built at about El. +13.5, grading to about El. +12.0 at the perimeter of the field.[4,5,6] El. 0 is mean low water at the Battery. The

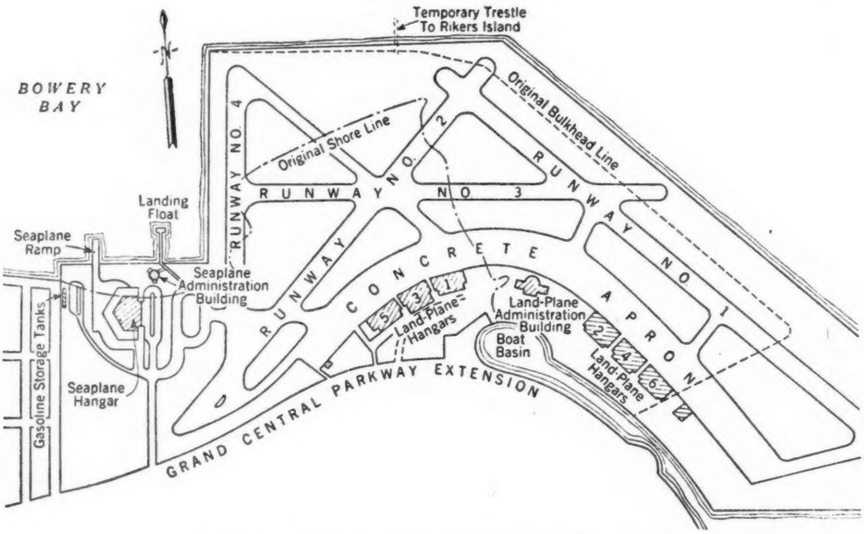

Fig. 1.—Plan of La Guardia Field, New York, N. Y.

Administration Building and the hangars in the southeasterly area (Nos. 2, 4, 6, and 8) were built on pile foundations. The piles were generally driven to bearing in the sand stratum underlying the soft silty clay, although in certain cases there is evidence that the penetration into the sand stratum was not accomplished, or that it was insufficient.

The Problem

With this background from the foundation standpoint, La Guardia Field may be divided into two parts: First, the part built on the original amusement park area plus the North Beach Airport area, which is founded on relatively

[4] "Ash Fill on Muck Base Airport," *Engineering News-Record*, June, 1938, p. 779.

[5] "Soil Investigation and Suggested Method of Subsoil Stabilization—Municipal Airport No. 2, La Guardia Field," by Madigan-Hyland Engrs., rept. to the Dept. of Marine and Aviation, City of New York, N. Y., October 17, 1946.

[6] "New York Municipal Airport," by Brehon B. Somervell, *Civil Engineering*, April, 1940, p. 201.

firm sand. (In these areas there has been practically no settlement of the runways, taxiways, or buildings.) The second part consists of extensions to the original airfield founded on a layer of miscellaneous fill about 20 ft thick on the average, overlying the soft silty clay stratum which varies from 0 ft to 60 ft in thickness. In these areas there was a settlement of about 5 ft in the 10 years since the airport was extended. This settlement has resulted in a series of problems which had to be solved if the airport was to continue in operation.

At the time the airfield was built, under the supervision of the United States Army Engineers predictions were made that settlement would continue for an indefinite period, and that, to maintain the field as an operating facility, it would be necessary to raise the grade periodically by the placing of additional fill. Because of conditions imposed by World War II and the necessity for avoiding any interruptions in the use of the field, it was found expedient to defer this filling operation. On several occasions prior to August, 1946, northeast winds combined with a high tide had driven water over the field, inundating the runways and putting the entire facility out of operation.

The problem then was how to rehabilitate the field without interfering with flying operations. Review of air traffic in the metropolitan area indicated that, because of the traffic density, it would not be possible to suspend operations at La Guardia Airport for the time necessary to build the field up to the original grades by the simple expedient of placing fill and then repaving. In any case, preliminary investigation indicated that placing necessary fill on the field would probably result in mud waves in adjacent areas and might even endanger the safety of the entire field by developing lateral displacements in the underlying strata.

The Solution

The initial studies conducted before proposals were made to the City of New York encompassed engineering analysis of possible solutions to the settlement problem and design studies of the ultimate cost of the stabilization and rehabilitation of the field. A number of possibilities were studied and rejected. Among them were the pile-supported concrete runways, the flotation of parts of the runways, and the construction of wholly supported runways built of structural steel and subway grating. All these suggestions were rejected because of excessive cost and because they did not appear feasible if field operations were to be maintained.

When the New York Port Authority assumed jurisdiction of the field, tests were immediately inaugurated to determine the practicability, the time required, and the cost of field stabilization. The system which appeared to offer the greatest promise of coping with the problem of the continued settlement of La Guardia Field was the installation of sand drains to stabilize substrata.

Sand drains have been used for a number of years (particularly on the west coast of the United States) with varying degrees of success. In certain types of installations which appear unsuccessful, the fault probably lies in attempting to apply excessive loads before the substrata have consolidated. The resultant slippage of the underlying material may well have sheared the sand drains so

that they were no longer effective. Sand drain technique, of course, lends itself particularly well to substrata such as that at La Guardia Field where the horizontal permeability is much higher than the vertical permeability. The installation of sand drains corrects this condition and allows the water to find its way up and out of the strata to be stabilized.

Sand drains consist of a vertical column of sand placed from the ground surface down into the layer to be stabilized. There are several satisfactory methods of installing these "piles" or drains. Briefly, the sequence of operations used at La Guardia Field was as follows:

1. The bottom of a mandrel is closed before driving by a removable steel plate.
2. A mandrel is pushed into the ground by the combined action of its own weight and a pile driving hammer.
3. When the mandrel is "home" (in this case, driven approximately 80 ft), sand is loaded in the hopper.
4. The hopper is raised and the sand flows into the mandrel.
5. The plate on the bottom of the mandrel is released; air is then applied at the top. This action of the air, together with a lift on the mandrel by the hoist, removes the pipe from the ground, leaving a column of sand.
6. Piezometer tubes are inserted in the test section to record the pore pressures in the underlying strata.
7. Surcharged load (in this case, 12 ft of sand in 2 ft increments) is added in stages to the test area.
8. Under the squeezing action produced by the surcharged load, part of the water contained in the silty layer underlying the sand is gradually squeezed up through the sand drains and discharged into the bay. An indication of this squeezing action is given by a drop in pressure on the gages attached to the piezometer tubes. As this water is gradually squeezed out, the surface of the field subsides and the underlying stratum becomes more stable.

Three sand drain test areas, each 100 ft by 100 ft, were installed to the east of La Guardia Field, with the spacing of drains in each direction, as follows:

Segment	Spacing, in feet
I	14
II	11
III	8

Piezometer tubes were installed and continuous readings were taken of the pore pressure in the substrata as small increments of surcharge load were added to the test section. Eventually, a total surcharge load of 12 ft was imposed on the test section. Thereafter, under the total loading, the rates of settlement were as recorded in Table 1 and as shown in Fig. 2.

The rate of consolidation during the period of driving sand piles and placing the surcharge was greater than the values in Table 1, but no rate of consolidation can be given accurately because of the varying increments of load and the varying time intervals between loading.

Sand piles were driven in all segments between August 20, 1947, and September 23, 1947, and the surcharge was completed by December 3, 1947. The total settlements are as shown in Table 2.

The results of these tests indicated that it was possible to stabilize La Guardia Field by installing sand drains. The problem then facing the Port

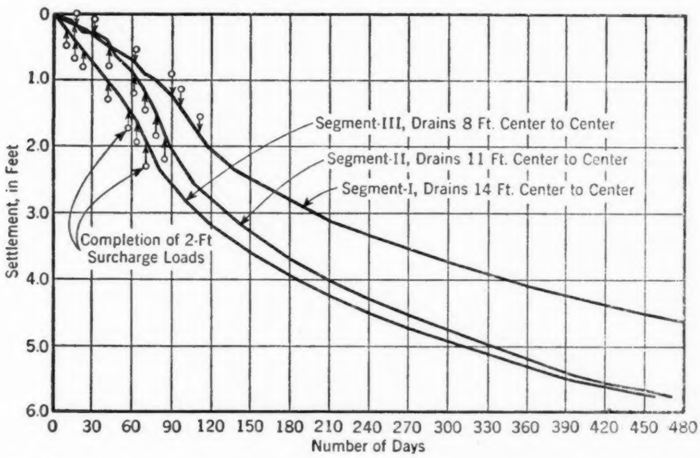

FIG. 2.—SETTLEMENT OBSERVATIONS ON SAND DRAINS FOR SUBSOIL STABLIZATION

Authority was how it could best use the results of this test to consolidate and protect the field from high water and still permit operations. The installation of sand drains throughout the areas of all runways, at best, would have been a serious handicap to the operation of the field, and some doubt exists as to

TABLE 1.—SETTLEMENT, IN FEET

Elapsed time, in days	Segments: I	II	III
Loading complete	Dec. 16, 1947	Dec. 4, 1947	Dec. 3, 1947
0 to 30	0.45	0.78	0.69
110 to 140	0.21	0.27	0.25
250 to 280	0.14	0.16	0.14

TABLE 2.—TOTAL SETTLEMENT, IN FEET

Segment	No. of Days After: Driving	Loading	Total, in feet
Loading Completed July 17, 1950			
I	1,055	950	6.43
II	1,040	962	7.55
III	1,027	963	7.38

whether it would have been possible to continue uninterrupted flying operations if it had been decided to install drains throughout the field.

A better solution presented itself: Experience at various airfields in the United States and in other areas in the world has indicated that it is possible to operate a field inside a dike, at an elevation even lower than the adjacent waters, with perfect safety, provided that the glide paths to the runways are protected adequately. The solution was the installation of an earth dike

around the perimeter of the low areas of La Guardia Airport where the maximum settlement had occurred; this dike was stabilized in such a manner that the erosion from the adjacent waters did not materially affect its integrity. In order to insure that this dike would not develop mud waves and itself be swept into the bay (particularly where the underlying mud was the deepest and the least stable), sand drains were installed in the area to be occupied by the dike before placing the dike fill. Work on this dike and the sand drains was begun on July 28, 1948, and was completed on August 15, 1949.

To provide for the field drainage, for the removal of rain water, and for the removal of water seeping through the dike, a ditch was built inside the dike proper. Three 36-in. runoff pipes with gravity-actuated tide gates were installed connecting the ditch to the bay. By draining the ditch at nonhigh tide periods, these pipes are sufficient for the normal flow due to seepage and for the collection of surplus water at periods other than those of maximum rainfall. Sumps and pumps in the ditch are provided to take care of drainage during abnormally high tides and periods of excessive rainfall.

It was necessary to raise the top of the dike by depositing additional fill at approximately 6-month intervals. When it has been determined that the strata under the dike itself are stable and will contain the field without danger of adjacent mud waves, it will be possible to raise the grade of the field by a simple filling and paving operation.

Summary

The entire operation to date (1950) has been conducted in such a manner that the field has been operable at all times. The high tides have not infiltrated through the dike.

The shore face of the dike is protected with stone macadam surfacing which resists erosion. Riprap rock fill has been installed along its outer face which protects it from the action of the high tides and the northeast winds. As heavy erosion and ice action are to be anticipated each winter in Flushing Bay, this facing is considered a necessity.

Because of the proximity of good fill on adjacent Port Authority property and by the simple expedient of erecting an earth-fill dike on a sand drain stabilized foundation, it has been possible to protect this vital air terminal and its airport operations have been maintained uninterruptedly.

Acknowledgment

The tests described in this paper were conducted under the direction of J. C. Evans, M. ASCE, chairman of the Engineering Board, Port of New York Authority, with the assistance of the following consultants: The late Frederic R. Harris, M. ASCE, and O. J. Porter and William Mueser, Members, ASCE.

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